AN EVALUATION OF THE USDA LIMB AND STALK REMOVER FOR CLEANING MACHINE-STRIPPED COTTON

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CONTENTS

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AN EVALUATION OF THE USDA LIMB AND STALK REMOVER FOR CLEANING MACHINE-STRIPPED COTTON

By Weldon Laird and Roy V. Baker[1]

INTRODUCTION

Cleaning machine-stripped cotton effectively for efficient ginning and acceptable quality remains a problem for many ginners. Generally, 75 to 90 percent of the foreign matter is removed from stripped cotton by conventional cleaning systems, applied in the usual manner. The remaining foreign matter interferes with the ginning process by lowering the operating efficiency of gin stands and increasing the trashiness of the lint. Both effects tend to increase the cost of ginning and to lower producer returns.

A relatively new cleaning principle has been incorporated into a machine known as the limb and stalk remover[2] and shows promise for improving the cleaning system of a gin that handles rough-harvested cotton. A saw cylinder is used in conjunction with a combing cylinder to remove limbs and stalks from seed cotton. The saw cylinder consists of saw-toothed discs stacked on a mandrel with a spacer between each disc. The combing cylinder has steel fingers which operate between the saw discs and move in the opposite direction to produce a combing action. Seed cotton is fed onto the top of the saw cylinder and pressed into the saw teeth by a stationary wire brush positioned near the saw periphery. The combing cylinder, located below the saw cylinder, combs foreign matter from the seed cotton. A doffing cylinder that follows the combing cylinder removes the remaining material from the saw and discharges it into a separate stream.

PURPOSE AND SCOPE

While the principle incorporated in the limb and stalk remover was intended for use on cotton containing large limbs and stalks, it also had possibilities for effective use on stripped cotton that contained smaller sticks and stems. The purpose of this investigation was to test the hypothesis that replacing one saw of a stick machine with the limb and stalk remover would improve stick removal from stripper cotton. Four separate tests were conducted in 1971 at the South Plains Cotton Ginning Research Laboratory, Lubbock, Tex.

Two sets of tests were conducted. One set was made to compare the combing principle of the limb and stalk remover with the sling-off principle of a stick machine. In the other set, various combinations of the limb and stalk remover and parts of the reclaiming section of a stick machine were tested. A standard stick machine was used as a control.

Equipment

The 96-inch limb and stalk remover model used in these tests was constructed at the Laboratory. A cross-section of the machine is shown in figure 1. The saw cylinder was constructed of ½-inch fiberboard discs and ¾-inch spacers. The discs and spacers were stacked on a conventional saw mandrel. The fiberboard

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[2]G.N. Franks and C.S. Shaw. New development for improvement of stick machines. The Cotton Gin and Oil Mill Press, 6(16): 7, 19. 1966.

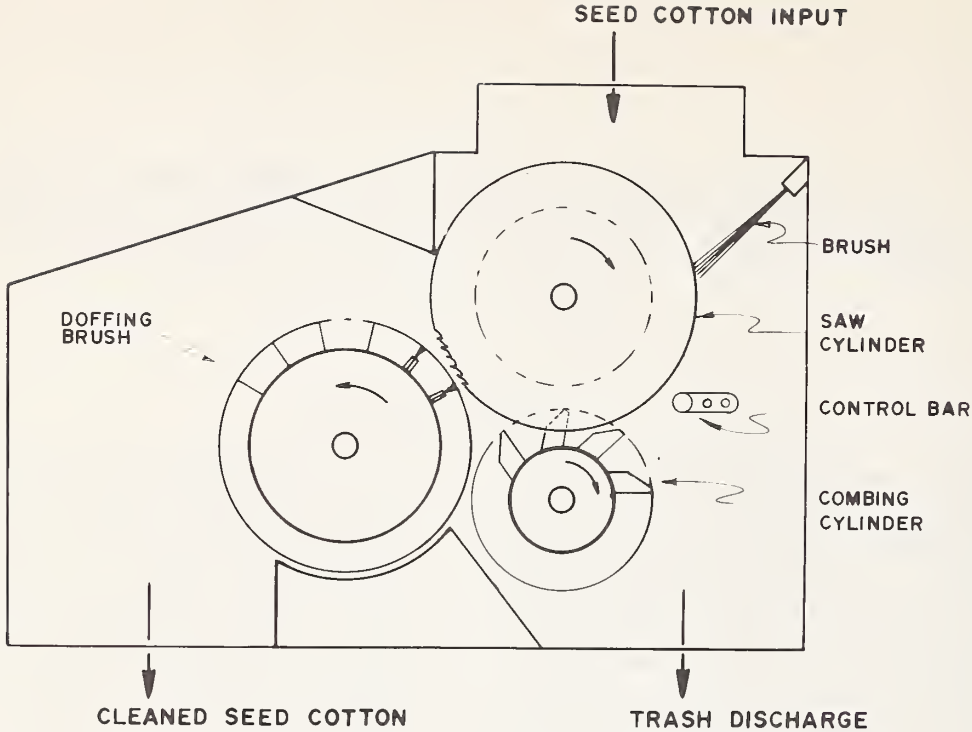

Figure 1.—Cross-section of the limb and stalk remover.

discs were 12 inches in diameter with conventional channel saws fastened to the periphery. The combing cylinder was constructed of 4 ½-inch-diameter tubing with eight rows of 1 ¾-inch-long steel fingers. The fingers were inclined forward 10°. The surface speed ratio between the saw and combing cylinders was 3.8 to 1. The cotton was brushed onto the saw cylinder by a 5-inch, steel wire brush and doffed by an 11⅝-inch-diameter doffing cylinder.

A commercial, 96-inch model stick machine with one 13 ¾-inch saw cylinder for primary cleaning and two 13 ¾-inch saw cylinders for reclaiming was used in the tests. (See figure 2.) The first saw operated at 376 revolutions per minute (r.p.m.), the second at 270 r.p.m., and the final reclaimer saw at 170 r.p.m. Two 1½-inch diameter grid bars were used with the primary saw and one with each of the reclaiming saws. The cotton was charged onto each of the saws by steel wire brushes and removed by 12-inch doffing cylinders. Modifications of ducting, baffling, and so forth were made to the stick machine to enable carrying out the different parts of the test. These modifications are described in the discussion of the appropriate test.

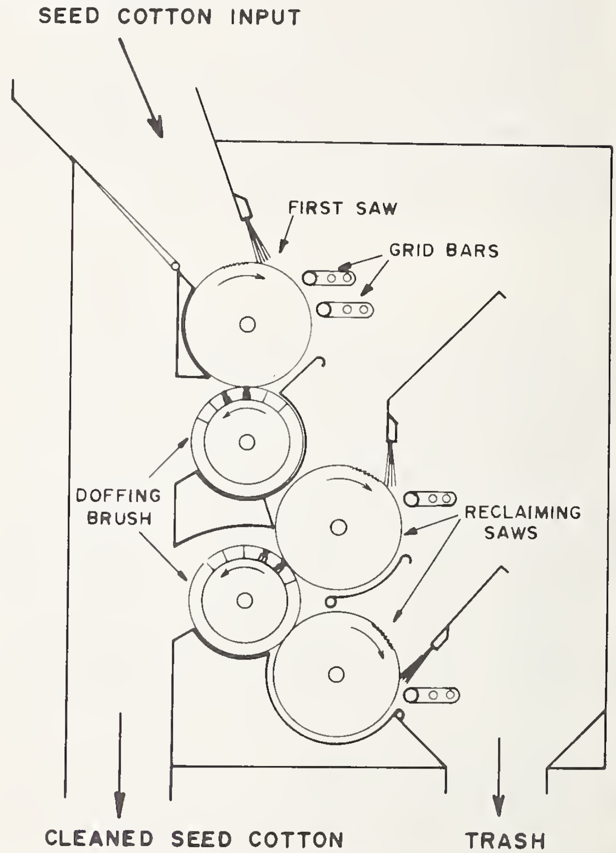

Figure 2.—Cross-section of the conventional stick machine.

Cylinder Comparison Tests

Two tests were designed and run to compare the performance of two types of saw cylinders—the limb and stalk remover and the primary saw cylinder of the stick machine. The tests were made under identical conditions of seed cotton foreign matter content, feed rate, and moisture content.

The limb and stalk remover was installed on top of the stick machine and operated interchangeably with the primary saw of the stick machine. Baffles were installed in the stick machine to route the trash around the reclaiming section so that the total material removed by the primary saw could be collected and analyzed.

In the first cylinder comparison test, two levels of precleaning systems—limited and extensive—were used so that the performance of the two saw cylinders could be tested at different levels of foreign matter content in bur cotton. The limited system included an airline cleaner and one 6-cylinder inclined cleaner; the more extensive system included an airline cleaner, two 6-cylinder cleaners, and a 14-foot bur machine. Each precleaning system was used on half of the twelve lots of cotton tested. The test was carried out as a 2×2 factorial experiment in randomized blocks with three replications of the four treatment combinations.

The stick machine's primary saw was operated at its normal speed of 376 r.p.m., and generated a centrifugal sling-off force of 27.6 g's. The saw cylinder of the limb and stalk remover was operated at a speed established by previous research—360 r.p.m. Under these conditions, the limb and stalk remover generated only 22.0 g's of centrifugal force.

Paymaster 909 cotton, harvested in mid-December 1970 and ginned in mid-January 1971, was used for this test. The average foreign matter content of the bur cotton was 17.2 percent burs, 7.6 percent sticks, and 3.7 percent fine trash after limited percleaning; and 3.2 percent burs, 3.7 percent sticks, and 3.2 percent fine trash after extensive precleaning. The more extensive precleaning system reduced foreign material content considerably, as was expected, because the system was more elaborate. This system also opened and fluffed up the cotton more than the limited system did.

TABLE 1.—Average pounds of foreign material removed per 200-pound lot by each of the two saw cylinders in the first cylinder comparison test (three replications) at two cleaning levels

Type of material	Limited precleaning		Extensive precleaning	
	L & S remover[1]	Stick machine	L & S remover[1]	Stick machine
	Pounds	*Pounds*	*Pounds*	*Pounds*
Burs	[2] 25.0 a	25.2 a	2.8 b	3.6 b
Sticks	11.1 a	8.8 b	4.0 c	3.7 c
Fine trash	3.8 a	4.0 a	1.5 a	1.7 a
Seed cotton[3]	34.4 a	10.9 c	22.6 b	24.7 b

[1] L & S remover is limb and stalk remover.

[2] For a given trash component, values followed by different letters are significantly different at the 5-percent level.

[3] The seed cotton removed by the limb and stalk remover saw represents losses of 24.7 percent and 16.2 percent at the limited and extensive precleaning levels, respectively, and losses by the primary saw of the stick machine of 7.8 percent and 17.7 percent, respectively, at the two levels.

The average amount of each type of foreign matter removed from each 200-pound lot of bur cotton by the two saw cylinders at the two levels of precleaning is given in table 1. The limb and stalk remover extracted significantly more sticks than the stick machine did from cotton that had high foreign matter contents. For cotton with low foreign matter contents, the difference in stick removal was not statistically significant. The two machines removed approximately equal amounts of burs and fine trash at each of the foreign matter levels.

The limb and stalk remover lost considerably more seed cotton than the stick machine primary saw when cleaning cotton that had received limited precleaning. Seed cotton losses of the two saw cylinders were about equal for cotton that had received extensive precleaning. Seed cotton losses appeared to be influenced by the amount of mechanical treatment the cotton received during precleaning. Seed cotton losses by the primary saw of the stick machine were lowest during the limited precleaning treatments, while losses by the limb and stalk remover were lowest during extensive precleaning treatments. Observations during the test indicated that, after limited precleaning, the seed cotton

consisted of groups of individual seed units connected together by fiber entanglements. These groups tended to wrap around the combing fingers of the limb and stalk remover and be pulled off the saw. Additional precleaning separated the seed units and reduced this type of loss. The stick machine tended to lose the single seed units more readily than the groups of several seed units.

The first test comparing the two types of saws was run under nearly identical operating conditions. However, as previously pointed out, the centrifugal forces generated by the two saws were not equal. In order to determine the amount of cleaning accomplished solely by the combing mechanism, it was necessary to compare the two saw cylinders when operating with equal centrifugal forces. To accomplish this, the speed of the limb and stalk remover saw was increased to 402 r.p.m. At this speed it generated 27.6 g's of centrifugal force—the same as the stick machine's primary saw. Therefore, differences in performance between the two saws should have been due, primarily, to the combing mechanism.

Since the limb and stalk remover was an experimental machine, two other saw speeds were also used in the second test to get additional information of its operating characteristics. The centrifugal force generated by the limb and stalk remover saw was calculated to be 22.0 g's at 360 r.p.m., and 51.5 g's at 550 r.p.m.

The second test was made using cotton of mixed varieties, harvested in January 1971 and ginned in early October 1971. To minimize variations within a replication, the cotton was precleaned with an airline cleaner and a 6-cylinder, inclined cleaner and divided into 200-pound test lots. Twelve lots were used for the three replications of the four test treatments. These treatments included the three operating speeds of the limb and stalk remover and the standard speed of the stick machine.

Seed cotton samples, taken after precleaning and before entering the test machine, showed no significant differences in moisture or foreign matter contents between lots subjected to the four treatments.

The moisture content of the cotton averaged 8.7 percent for all test cotton. The amounts (in pounds) of foreign matter contained in the seed cotton before and after the test machines are given in table 2. The data is presented on a pound basis rather than percentage because unequal seed cotton losses by the two machines introduce ambiguities into the after treatment data when percentage is used.

Even though the seed cotton was blended before the test, large variations in foreign matter contents were still present in the test material. Because of these variations, only the large differences between treatment means were statistically significant. However,

TABLE 2.—Second comparison test of foreign matter contents in precleaned seed cotton before and after cleaning by two types of saw cylinders at different centrifugal forces (g's) in pounds per 200-pound bur cotton lot; average of three replications

Foreign matter content	Type of saw cylinder and centrifugal forces generated			
	Limb and stalk remover			Stick machine
	22.0 g's	27.6 g's	51.5 g's	27.6 g's
Before test machine:				
Burs	[1] 37.80 a	38.20 a	37.44 a	39.35 a
Sticks	12.83 a	12.83 a	12.97 a	14.12 a
Fine trash	8.10 a	9.11 a	9.02 a	8.57 a
Total	58.73 a	60.14 a	59.43 a	62.04 a
After test machine:				
Burs	11.53 a	10.57 a	7.75 a	12.40 a
Sticks	5.02 ab	4.49 ab	3.28 a	7.03 b
Fine trash	4.24 a	3.88 a	3.87 a	5.87 b
Total	20.79 ab	18.94 ab	14.90 a	25.30 b

[1] For a given trash component, values followed by different letters are significantly different at the 5-percent level.

definite trends were established as shown by the data in table 2. The amount of foreign matter that remained in the cleaned seed cotton tended to decrease with each increase in speed of the limb and stalk remover saw, indicating that the increase in centrifugal force from 22.0 to 51.5 g's had a positive effect upon foreign matter removal. The data also indicated that when the two types of saw cylinders were operated with identical centrifugal forces, the limb and stalk remover saw extracted the most foreign matter. This additional extraction by the limb and stalk remover saw indicated the contribution made by the saw's combing mechanism.

The average cleaning efficiences of the two saw cylinders are shown in figure 3. An

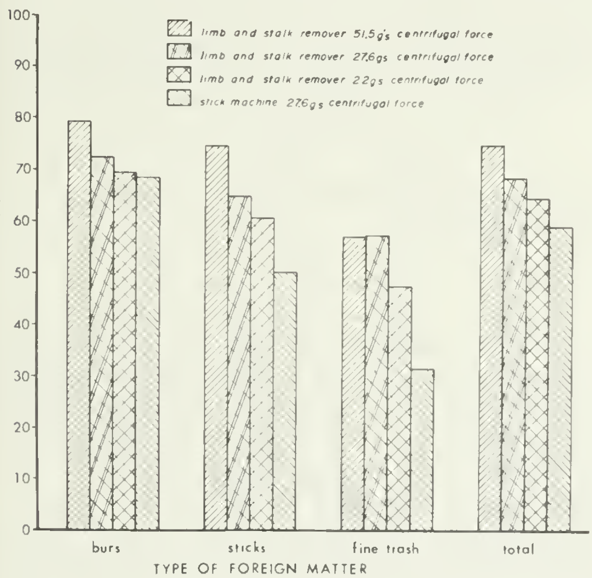

Figure 3.—Average cleaning efficiencies of two types of saw cylinders, second cylinder comparison test, October 1971.

examination of these bar graphs shows that the cleaning efficiency of the limb and stalk remover saw was higher than that of the primary saw of the stick machine for all speeds tested. The largest efficiency differences were obtained for stick and fine trash removal, indicating that the combing principle did give worthwhile increases in cleaning efficiency when combined with the sling-off principle now used in stick machines.

The amount of seed cotton lost by the limb and stalk remover did not increase directly with the speed. The limb and stalk remover lost 21.9 percent of the seed cotton when it was operated at 360 r.p.m., 27.2 percent at 402 r.p.m. and 24.8 percent at 550 r.p.m. The stick machine saw lost 6.6 percent of the seed cotton in this test—or approximately one-fourth as much as the limb and stalk remover.

The two tests made for comparing the limb and stalk remover saw with the primary saw of the stick machine established that the addition of the combing mechanism to the sling-off saw gave worthwhile increases in stick removal efficiency on machine-stripped cotton. The tests also showed that the increase was greater on cotton with higher foreign matter contents. A problem revealed by the tests was the extra amount of seed cotton removed with the trash when the combing mechanism was used.

Reclaiming Tests

Two additional tests were conducted to determine if the extra seed cotton removed with the trash could be reclaimed satisfactorily. Three combinations of the limb and stalk remover with the contentional stick machine were used in two tests. In the first test, the limb and stalk remover was installed above the conventional stick machine. Sheet metal ducts were provided to carry the trash from the limb and stalk remover to the reclaiming section of the stick machine, and the cleaned seed cotton from the limb and stalk remover into the inlet above the top saw of the stick machine. One treatment allowed the clean seed cotton to go through the top saw for additional cleaning, figure 4 #A. Another treatment bypassed the seed cotton around the top saw, figure 4B. The third treatment bypassed the limb and stalk remover and fed the bur cotton directly to the top saw of the stick machine in the usual manner, figure 4C.

The third possible combination of the two machines (use of the entire stick machine to reclaim seed cotton from the trash discharged by the limb and stalk remover) was evaluated in the second test.

In both tests, two levels of precleaning were used to provide cotton with different foreign matter contents. The two levels of precleaning were the same as those described previously in the cylinder comparison tests.

In the first test, fractionation samples were taken of the seed cotton at each step in the

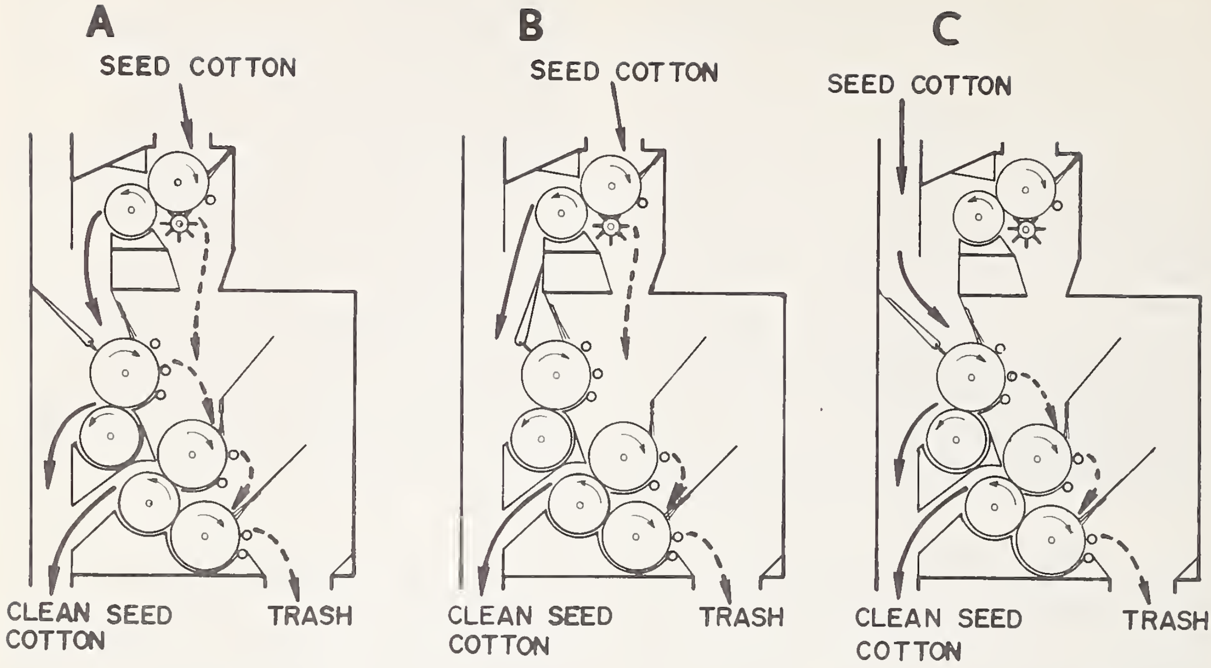

Figure 4.—Schematic diagram of the three combinations of the limb and stalk remover with the stick machine as they were used in the first reclaiming test.

cleaning sequence. Moisture samples were taken from the seed cotton after precleaning and from the ginned lint before lint cleaning. Lint samples were taken before and after lint cleaning. The trash discharged by the test machines from each lot was weighed, and fractionation samples were taken.

The first reclaiming test was set up as 2×3 factorial experiment, consisting of two levels of precleaning and three machine configurations. Four replications were carried out in randomized blocks. The test cotton was ginned January 20 and 21, 1971,. Approximately five bales of Paymaster 909 cotton, harvested in mid-December 1970, were used for the test. Four to five hundred pounds of seed cotton were ginned for each replication. The seed cotton was processed through the test machines at rates of approximately 5.3 bales per hour.

The foreign matter contents of the test cotton on the wagon averaged 17.9 percent burs, 6.5 percent sticks, and 7.5 percent fine trash. Precleaning reduced the foreign matter contents and produced seed cotton with two levels of foreign matter, table 3. The stick contents as measured by the fractionation test increased after the limited precleaning. This was probably a result of the peduncle being broken free from the bur by precleaning and remaining in the seed cotton where it appeared as a stick in the fractionation test.

The foreign matter contents of the seed cotton entering and leaving the test machines are given in table 3. There were no significant differences in foreign matter contents between lots of seed cotton subjected to the three treatments at either level of precleaning. Foreign matter contents after the treatments showed significant differences produced by the test machines on cotton which had received limited precleaning, but not on cotton which had received extensive precleaning. The foreign matter contents of cotton cleaned by the stick machine were slightly lower than those for cotton cleaned by either combination of the limb and stalk remover with reclaiming.

These foreign matter contents were used to calculate the cleaning efficiencies shown in figure 5. Treatments are: A, limb and stalk remover and stick machine combined; B, limb and stalk remover with reclaiming section of stick machine; and C, conventional stick machine.

TABLE 3.—Average percentages of foreign matter in the precleaned seed cotton before and after cleaning in the test machines—first reclaiming test; four replications

Foreign matter contents	Limited precleaning treatment[1] of—			Extensive precleaning treatment[1] of—		
	A	B	C	A	B	C
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Before test machine:						
Burs	17.28	17.78	17.61	3.13	3.21	3.19
Sticks	9.51	9.08	9.27	5.02	4.77	4.32
Fine trash	3.78	3.95	4.38	3.39	2.92	3.19
Total	30.57	30.81	31.26	11.54	10.90	10.70
After test machine:[2]						
Burs	9.33 b	10.29 a	8.11 c	1.57 d	1.60 d	1.60 d
Sticks	3.99 b	4.79 a	3.76 b	1.83 c	2.28 c	1.74 c
Fine trash	5.06 a	5.25 a	4.96 a	3.59 b	3.53 b	3.34 b
Total	18.38	20.33	16.83	6.99	7.41	6.68

[1] Treatments are: A, limb and stalk remover and stick machine combined; B, limb and stalk remover with reclaiming section of stick machine; and C, conventional stick machine.

[2] For a given trash component, results followed by a different letter are significantly different at the 5-percent level.

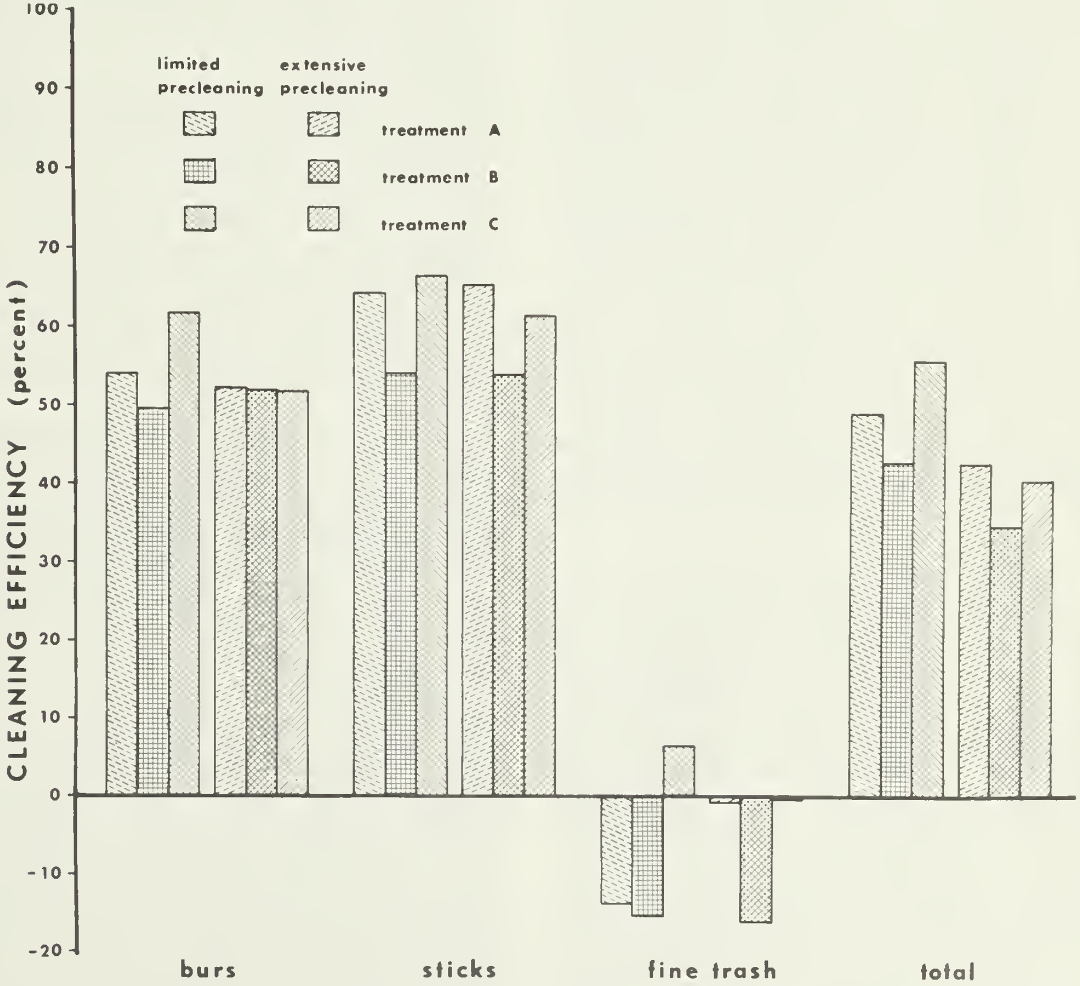

Figure 5.—Foreign matter removal efficiency of the test machines after two levels of precleaning, first reclaiming test, January 1971.

Cleaning efficiency (E) on burs, sticks, and fine trash,

$$E = 100\left(1 - \frac{n_2 - n_2 N_1}{n_1 - n_1 N_2}\right)$$

and on total trash,

$$E = 100\left(1 - \frac{N_2 - N_2 N_1}{N_1 - N_1 N_2}\right) \text{ where:}$$

n_1 = trash factor content before test machine,

n_2 = trash factor content after test machine,

N_1 = total trash content before test machine,

N_2 = total trash content after test machine.

The two combinations, using the limb and stalk remover with reclaiming, were generally less efficient than the stick machine alone. The level of precleaning had only a slight effect upon the efficiencies of the limb and stalk remover combination. Precleaning did affect the efficiency of the stick machine which was more efficient on the trashier cotton. Fine trash removal efficiency was negative in every case except one, indicating that the machines tested actually generated more fine trash, by breaking up burs and sticks into fine trash particles, than they removed.

Foreign matter contents of seed cotton at the feeder apron still showed the effects of the treatments. These differences were also apparent in the nonlint contents of the ginned lint. Some of the lots that had received limited precleaning had over 2 percent stick content at the feeder apron. Lint samples from all of these lots were reduced in grade because of excessive bark.

The results of this test appear to contradict those from the tests in which the two saw cylinders were compared without reclaiming. These results indicated that reclaiming was responsible for the lower cleaning efficiencies obtained in this test. Also, the extra amount of seed cotton removed by the combing mechanism overloaded the reclaiming section and caused it to reentrain much of the foreign matter back into the cleaned seed cotton.

Because of this, some modifications were made to the machinery and a second test was run, using the entire stick machine for reclaiming. Thus, it was possible to use the primary saw of the stick machine to reclaim some of the seed cotton and to reduce the amount of material being fed to the reclaiming section. The limb and stalk remover saw was operated at 360 r.p.m. in this test.

A more elaborate sampling procedure was adopted to determine the performance of each section in the limb and stalk remover-stick machine combination. The material coming from the doffing cylinders of each section was collected, weighed, and sampled. This made it possible to determine the destination of each type of material on a pounds basis as well as a percentage basis, eliminating ambiguities involved in using percentages alone. The construction of sheet metal ducts and containers was required to keep the material from each section separate.

This test was ginned May 7 through 12, 1971. Semistormproof cotton, harvested in January 1971 and stored under a shed until the time of ginning, was used. One hundred pounds of bur cotton were used for each treatment combination.

The bur cotton on the wagon averaged 7.5-percent moisture, 21.5-percent burs, 5.8-percent sticks, and 7.1-percent fine trash. Two levels of precleaning were again used to provide cotton with two levels of foreign matter. The average foreign matter contents of the seed cotton after limited precleaning were 17.3-percent burs, 6.1-percent sticks, and 4.1-percent fine trash and after extensive precleaning were 6.5-percent burs, 4.3-percent sticks, and 4.6-percent fine trash.

The results obtained in this test are given in table 4. The limb and stalk remover saw extracted a large amount of the burs and sticks from the seed cotton. Bur and stick removal efficiencies were in the 64.3- to 72.9-percent range. Along with the foreign matter, the limb and stalk remover also lost 10 to 17 percent of the seed cotton. All of this material was fed to the stick machine for reclaiming. The stick machine reclaimed practically all of the lost seed cotton but also reentrained large amounts of foreign matter back into the cleaned seed cotton. This caused a drastic reduction in the overall cleaning efficiency of the limb and stalk remover-stick machine combination.

The material reclaimed by the primary saw and reclaiming section of the stick machine was examined, and the results are given in table 5. These data show that the material

TABLE 4.—Results from cleaning bur cotton, having two levels of foreign matter contents, in the limb and stalk remover with the entire stick machine for reclaiming; average of four replications

Type and content level of foreign matter	Initial content of test lot	Amounts removed by limb and stalk remover saw		Amounts reentrained by by reclaiming section	Overall efficiency of combination
	Lb./bale	*Lb./bale*	*Percent*	*Lb./bale*	*Percent*
Burs:					
High	397	270	68.0	179	22.9
Low	150	110	72.9	40	46.0
Sticks:					
High	141	91	64.3	46	31.9
Low	99	72	72.5	23	49.5
Fine trash:					
High	94	37	39.6	29	8.8
Low	106	50	47.7	16	32.5

TABLE 5.—Composition of the material reclaimed by the stick machine in the second reclaiming test; averages of four replications

Type and content level of foreign matter	Primary saw[1]	Reclaiming section[1]
	Lb./bale	*Lb./bale*
Burs:		
High	26.2	152.5
Low	5.5	35.0
Sticks:		
High	10.81	35.42
Low	6.67	17.02
Fine trash:		
High	14.49	14.03
Low	10.12	5.75
Seed cotton:		
High	250.24	27.6
Low	169.74	35.4

[1] The primary saw reclaimed approximately 86 percent of the lost seed cotton and the reclaiming section approximately 14 percent.

reclaimed by the primary saw was actually cleaner than the cleaned seed cotton. The primary saw reclaimed approximately 86 percent of the lost seed cotton while reentraining only a small amount of the foreign matter. The reclaiming section reclaimed the remaining 14 percent of the lost seed cotton but also reentrained a large amount of the foreign matter—especially burs. This shows that the reentrainment problem was limited to the reclaiming section.

SUMMARY AND CONCLUSION

Machine-stripped cotton contains large amounts of sticks and stems which are difficult to remove at the cotton gin with present day equipment. A new combing principle used in the USDA limb and stalk remover shows promise as an improved stalk remover. It uses a combing mechanism in addition to sling-off action to remove foreign matter from seed cotton. A conventional stick machine relies solely upon sling-off forces to extract foreign matter. To determine the contribution to cleaning efficiency made by the combing mechanism, tests were conducted which compared the limb and stalk remover to the primary saw of a conventional stick machine. The combing mechanism gave significant increases in stick removal efficiency, especially when the foreign matter contents of the seed cotton were high. The combing mechanism also lost considerably more seed

cotton than the primary saw of the stick machine. Various combinations of the limb and stalk remover with reclaiming sections of the stick machine were tested to see if the seed cotton could be adequately reclaimed. The seed cotton was reclaimed by all the combinations tested, but the increase in cleaning efficiency gained by the use of the combing mechanism was lost during reclaiming because the systems tested reentrained large amounts of foreign matter back into the cleaned seed cotton.

These tests demonstrated that the combing mechanism of the limb and stalk remover gave worthwhile increases in cleaning efficiency. However, before such a mechanism can be used on a practical basis, the amount of seed cotton lost with the trash will have to be reduced, a better reclaiming system developed, or both.

The results from these two reclaiming tests showed that all reclaiming systems tested were adequate to hold seed cotton losses to acceptable levels. However, all of the systems tested reclaimed too much of the trash to be practical for use with the limb and stalk remover. The increase in cleaning efficiency gained by the addition of the combing mechanism always disappeared during reclaiming.

RECOMMENDATIONS

Research is needed in two areas in order to take advantage of the improved stick removal capabilities of the limb and stalk remover. The relationships between the various design factors of the combing mechanism and the cleaning characteristics of stripped cotton need to be investigated further to obtain an optimum machine design. Also, alternative methods for reclaiming seed cotton are needed in order to find a more efficient reclaiming system that is compatible with the efficiency of the limb and stalk remover.